

THE HARTLEY-KRAUSE FLAP IN HÆMORRHAGE FROM THE MIDDLE MENINGEAL ARTERY.

WITH REPORTS OF TWO CASES.¹

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IN 1891 and 1892, Hartley, of America, and Krause, of Germany, each working independently, devised a method of resecting the trigeminus nerve intracranially by means of an osteoplastic resection of the skull in the manner originated by Wagner. Hartley's first case was operated upon August 15, 1891 (or, as stated in his second article, August 8, 1891), and Krause's, February 23, 1892. Hartley's case was reported to the New York Surgical Society, January 13, 1892; Krause's to the German Surgical Society at its Twenty-First Congress in Berlin, June 10, 1892. Hartley's¹ case was published March 19, 1892, and Krause's,² October 11, 1892. Thus it is seen that, while Hartley's case was operated upon before Krause's, and also published before Krause's was published, Krause's case was operated upon before Hartley's case was published.

Hartley, in a second article on this subject in May, 1893,³ claims priority for the operation, a claim which, I believe, is not disputed.

Hartley, in his first article, describes his flap as follows:

"An Omega-shaped incision was made, having its base at the zygoma and measuring a distance marked by a line drawn

¹ Read before the Chicago Surgical Society, May 5, 1902.

from the external angular process of the frontal bone to the tragus of the ear.

"The curved and rounded portion of this incision reached as high as the supratemporal ridge, the diameter of said circle being three inches. The skin and deeper tissues were cut in the shape of the Greek capital letter Omega. The incision was carried down to the periosteum of the skull in all portions of the incision except in the straight part at the base; the tissues were then retracted and the periosteum divided upon the bone in the same direction and as far as the straight part at the base.

"With a chisel a groove was cut in the bone corresponding to the divided periosteum. This groove went to the vitreous plate, except at the upper angle over the rounded portion, where it included the vitreous plate.

"A periosteum elevator was here inserted and used as an elevator to snap the bone on a line between the ends of the circular portion of the incision. In this way the breakage occurs along the lower portion of the wound, and a flap, consisting of skin, muscle, periosteum, and bone, is thrown down, exposing the dura mater over a circular area of three inches in diameter."

In his second article,⁴ Hartley says: "I do not find it necessary to complete the Omega cut, as the lower straight part of the Omega incision is unnecessary. The periosteal incision converges upon each extremity beneath the muscle-flap for about one-half a centimetre, so as to cause a cleavage in the bone when elevated. This part of the periosteal incision is made by retracting the skin and muscle-flap slightly upon each side. The point at which the periosteal incisions converge is just at the level of the zygoma."

Krause⁵ describes his flap as follows: "The pedicle of the flap lies above the zygoma. The incision begins in front of the tragus, mounts upward bending convexly backward, and then describes an arch about semicircular in form, and proceeds forward, likewise convexly, to the malar bone, in such a manner that the base of this uterus-shaped flap is three and a quarter centimetres across, its height six and a half centimetres, its greatest width, lying above, five and a quarter centimetres."

It will be seen that this flap corresponds very closely to Hartley's.

Each of these writers intended his flap to be used for intracranial resection of the fifth nerve. However, Krause adds, in a foot-note to his article, "My incision serves well for the purpose of ligating the main trunk of the middle meningeal artery." Hartley, in the description of his first operation, says "the middle meningeal artery was tied," but says nothing of the use of his flap for the purpose of exposing the artery.

In an article by the writer,⁶ giving the results of original investigations on the middle meningeal artery, one of the conclusions was as follows: "That we have in the Hartley-Krause osteoplastic flap the only method fulfilling all the requirements for an ideal exposure of the middle meningeal artery and its branches." Although this conclusion was based solely upon my own researches, it was by no means an original conclusion, since Steiner,⁷ in 1894, concludes that this method is of so great superiority that we now have no use for the more defined locations of other methods except where some contraindication to the formation of the flap is present. These contraindications he names as the presence of a compound fracture or great injury to the soft parts.

The method was tested by Steiner as well as by myself upon the cadaver, and the conclusion in each case was based upon anatomical rather than practical surgical considerations. In every case the main trunk and anterior and posterior branches were rendered accessible.

To Krönlein⁸ we owe much for classifying the hæmatomata resulting from rupture of the middle meningeal artery or its branches according to their anatomical locations, and for pointing out definitely the objects to be accomplished in exposing the interior of the cranium in case of such arterial rupture.

Krönlein divides all extradural hæmatomata originating in rupture of the middle meningeal artery or its branches into I. Diffuse and II. Circumscribed.

Of the diffuse hæmatomata he says: "They are of great extent, covering almost the entire concavity of the affected area of the cranium."

Of the circumscribed he says: "They can be extensive, but one part of the dura mater is always adherent to the concavity of the skull. These haematomata have a sharp border, and are generally oval or circular in outline, their greatest thickness corresponding rather exactly to the centre."

He subdivides the circumscribed haematomata into three anatomical groups:

1. Hæmatoma medium, or temporoparietal.
2. Hæmatoma posticum, or parieto-occipital.
3. Hæmatoma anticum, or frontotemporal.

Of these three the hæmatoma medium is by far the most frequent. This occupies the middle fossa of the skull, and is generally bounded anteriorly by the lesser wing of the sphenoid, posteriorly by the petrous portion of the temporal bone, reaching inferiorly to near the foramen spinosum and superiorly to, or frequently beyond, the squamous suture. The greater frequency of this group is accounted for by the greater vulnerability of the temporal region and the richness of vessels, this region including the main trunk and anterior and posterior branches.

The hæmatoma posticum is decidedly rarer. This occupies the region below the parietal eminence, leaving the middle fossa quite free, and reaching generally to the falx cerebri above, to the occipital protuberance behind, and to the tentorium cerebelli below.

The hæmatoma anticum is the rarest of the three. This occupies principally the region of the frontal eminence, separating part of the dura mater from the orbital plate below, and extending posteriorly to or beyond the anterior inferior angle of the parietal bone.

As to the objects to be accomplished in exposing the site of the hæmatoma, Krönlein says: "We have to do, in the first place, not with checking haemorrhage, but with the removal of the extravasation which is already present and is dangerous. In cases of difficult diagnosis the haemorrhage has generally ceased at the time of operation." In a second article⁹ he emphasizes the judgment that the position of the

haemato^ma and not the anatomical position of the middle meningeal artery must decide the site for opening the skull.

Wiesmann¹⁰ agrees with Krönlein that the removal of the clot is of prime importance.

In regard to ligation in continuity of the artery in the place of election, Krönlein, in his first article says: "It might promise, in case the haemorrhage continued, only a doubtful result, if the vessel lesion lay immediately peripherally in the anterior branch." In his second article he says: "It could be of value only when the artery happened to be ruptured in the place of exposure and both ends could be tied. This would be really not a ligation in continuity, but a ligation in *loco lesionis*. In all other cases the ligation in continuity has no value. As I showed in 1882 (Wiesmann's²⁹ Case No. 10), a divided middle meningeal artery bleeds from both ends, so that its ligation in continuity could promise no absolute success."

Wiesmann¹⁰ deals curtly with the question of ligation in continuity: "There is no sense in ligating in continuity in the place of election after trephining."

We cannot but agree with these authorities that our first and most important, oftentimes our sole, object in opening the skull is the removal of the clot which by its pressure is threatening the patient's life. The question of the site of operation, then, must rest upon practical surgical considerations rather than upon anatomical; in other words, it is the position of the clot rather than the location of the artery that must guide us. Practically, the exposure and removal of the clot leads naturally to the discovery of the arterial lesion, so that the artery can be secured, if still bleeding. Wiesmann¹¹ notes that frequently the centre of the convexity of the clot corresponds rather closely to the site of rupture of the artery.

When, then, can the clot most certainly be reached? Krönlein,¹² in his first article, recommends that where there is no sign of value on the skull or its coverings, as a routine practice we trephine first in the temporal region at about the anterior inferior angle of the parietal bone; in other words,

at the location of choice for the ligation of the middle meningeal artery. Here we, as a rule, reach the anterior branch. His reason for choosing this site he states as follows: "We can, almost without exception, succeed in finding here the diffuse haematoma, and the circumscribed temporoparietal and frontotemporal. Only the circumscribed parieto-occipital haematoma cannot be reached from this place."

If, then, feeling sure of the diagnosis, the surgeon fails to expose the haematoma by trephining in the temporal region, he must assume that he has to do with a circumscribed parieto-occipital haematoma. In such a case Krönlein recommends that the surgeon proceeds to a second trephining under the parietal eminence.

In his second article, Krönlein¹³ modifies his advice slightly, advising that the choice as to which place to trephine first and whether to combine one trephining operation with another, and, in such a case, in what order, must be decided by exact observation of the patient before and during the operation.

In this article he reports a case where he trephined primarily below the parietal eminence. He was led to do so through having an accurate statement that the patient struck the back of his head on a beer-barrel, and by finding a slight suggillation a little to the left of the middle line in the occipital region. In this case the clot was exposed immediately at the trephine opening, but was not entirely removed, as it extended so far towards the base as to be out of reach. The patient did not regain consciousness, and developed a bronchopneumonia which was the immediate cause of death. The autopsy showed that the haematoma extended to within 1.5 centimetres of the foramen magnum. Krönlein recommends that in such a case an additional trephine opening should be made in the occipital region, somewhat behind the mastoid process in the middle of the inferior curved line of the occipital bone.

How accurate a localizing diagnosis is possible? Sir Astley Cooper¹⁴ said: "I do not find any difference of symp-

toms produced by the different situations of the blood; whatever is the situation of the blood, the symptom of compression is the same."

Wiesmann,¹⁵ however, points out a number of localizing symptoms which may be observed at times. Thus, an isolated paralysis of the opposite arm would point to the middle part of the central convolutions as the seat of the lesion; an isolated or very strongly marked facial paralysis points to an extravasation low down anteriorly. Unilateral disturbances of sensibility point with great probability to a haematoma posticum. Aphasia, a rare symptom, is due to pressure on Broca's convolution on the left side, and points to a haematoma anticum or a very large haematoma medium. The pupillary symptoms are very variable, but when they differ on the two sides, the dilated pupil is on the affected side in the majority of cases, but not invariably. Choked disk, if present, is on the side of the lesion. Disturbances of innervation of the eye-muscles are generally due to direct lesion or pressure within the cranial cavity, and so may assist in localizing the lesion.

Unfortunately, it is only exceptionally that findings leading to an accurate topical diagnosis are demonstrable. Krönlein¹⁶ says: "If the surgeon could see the case from the time of injury and follow the development of symptoms, and if the case were not complicated by concussion of the brain, contusion of the brain, apoplectic foci in the brain substance or acute alcoholism, then we could hope for more in the direction of topical diagnosis. But how seldom are all these conditions fulfilled! In complicated cases without history the surgeon is glad to make a diagnosis in general, or to know on which side to trephine. We think that in the preponderating majority of cases a further refinement of diagnosis cannot be thought of."

In his second article, Krönlein¹⁷ says: "In closed skull coverings we have only the brain symptoms to lead to a diagnosis, and we are generally lucky if we can tell upon which side the lesion is. Sometimes we can go a step farther and make a probable diagnosis of the location of the haematoma

in a certain region. When this is accomplished, it is all that we can do in the way of exact diagnosis."

The most important help in deciding upon which side the lesion lies is the gradually appearing hemiplegia, which may be preceded first by spasms, then by paresis. Difficulty in deciding which is the paralyzed side arises in cases of deep coma. It is claimed by some observers that instead of the usual paralysis of the side opposite the lesion, the so-called contralateral hemiplegia, we may have paralysis of the same side as that of the lesion, the so-called collateral hemiplegia. Oppenheim (quoted by Wiesmann¹⁸) looks upon these cases with suspicion as to the accuracy of the observations.

It appears, then, that in the great majority of cases we can determine upon which side the lesion is, and nothing further as to its location; also, that the great majority of the haematomata can be reached by opening the skull in the temporal region at about the anterior inferior angle in the parietal bone. Hence, it is seen that the best site for opening the skull, based upon practical surgical considerations, coincides with that best adapted for reaching the anterior branch of the middle meningeal artery, based upon anatomical considerations.

In my former article¹⁹ I said: "I regard the (Hartley-Krause) osteoplastic flap as the ideal method of reaching the middle meningeal artery, for by it the removal of the clot, which is generally present when this operation is done, is facilitated, and the artery can be ligated in the most desirable location." On the strength of Krönlein's practical deductions, I wish here to reaffirm and emphasize this statement, since by this method we expose the temporal region better than by any other.

An advantage of the osteoplastic flap which has not been alluded to is that it leaves no bony defect. At the time of operation the dura is removed some distance from the inner surface of the cranium by the presence of the clot. Upon removal of the clot the brain does not at once expand and press the dura back into its normal position; sometimes this process

requires several days. As a consequence of this, portions of bone removed by the trephine, chisel, or rongeur forceps cannot be replaced, as there is nothing to support them from beneath. The bone in the osteoplastic flap, on the contrary, can easily be made to resume and retain its normal position.

Krönlein says that a trephine opening in the temporal region will not expose a hæmatoma posticum. In Fig. 2 I have outlined the flap upon Krönlein's diagram of the three hæmatomata, and it will be seen that its posterior superior border touches the edge of the hæmatoma posticum. Of course, this hæmatoma has no definite limits; but if it is of comparatively large size and extends pretty well forward, its anterior edge will be exposed at the posterior superior border of the flap, as shown in my second case, here reported. If no hæmatoma is exposed, upon turning down the flap, the opening may be enlarged towards the parietal eminence, or the hæmatoma posticum may be sought for by a trephine opening in that region, as Krönlein suggests.

The cases in which no clot is present in case of torn middle meningeal artery are, first, those rare ones mentioned by Wiesmann²⁰ in which the artery does not bleed, and, second, those in which there is a compound fracture which permits the blood to escape externally.

The artery is always found beneath the clot, adhering to the dura. Hartley²¹ called attention to this adherence of the artery to the dura, as did also the writer,²² who demonstrated a process of the dura covering the outer surface of the artery, causing a firm adherence between these two structures, and inferred "that in cases of extradural hæmorrhage the artery would be found beneath the clot in all cases."

So far as I know, every observation, operative or post-mortem, in cases of extradural hæmorrhage has borne out the correctness of this inference. A possible exception can be imagined where the artery might be "held in contact with the bone by running in a canal."

In a considerable percentage of cases, 60 per cent. according to my findings,²³ 38 per cent. according to Steiner,²⁴ the

artery runs for a short distance at the anterior inferior angle of the parietal bone in a bony canal, and in such cases it is ruptured in turning down the flap. This, however, as pointed out by Hartley and the writer, is not of serious moment, as the ruptured end is in full view and easily secured.

The earliest recorded case which I can find of osteoplastic resection of the skull for intracranial haemorrhage was reported by Stenzel.²⁵ The flap he describes as follows: "A pedicled flap three to four centimetres in diameter was made beginning three centimetres back of the external angular process of the frontal bone." Thus it is seen that his flap, while exposing the same region as the Hartley-Krause flap, was smaller than the latter. This exposed the extravasation, which lay somewhat below and behind. Clot removed with the fingers; haemorrhage began again; source could not be found. Iodoform gauze packing. Recovery.

It is not certain that this was a hemorrhage from the middle meningeal artery. Stenzel's diagnosis was "haemorrhage following fracture of the base."

In discussing this case, Krause said: "For ligating the main trunk of the middle meningeal artery, I recommend the same flap which I proposed for trigeminus resection."

Steiner²⁶ says that in 1893 Wölfler used the osteoplastic flap for middle meningeal haemorrhage, and in a second case used a flap five centimetres broad and eight centimetres high.

Wiesmann²⁷ says that Nasse also used the osteoplastic flap for middle meningeal haemorrhage.

CASE I.—Rupture of Right Middle Meningeal Artery, Anterior Branch; Subcutaneous Fracture of Squamous Portion of Temporal Bone and of Base of Skull; Compression of Brain; Haematoma Medium; Haemorrhage into Fourth Ventricle; Free Interval; Contralateral Hemiplegia preceded by Spasms; Osteoplastic Resection of Skull; Removal of Clot; Ligation of Ruptured Artery; Death Ten Hours after Injury. Ante-mortem temperature, 107° F.; post-mortem, 109.5° F.

P. G.; aged thirty-five years; male. On February 3, 1899, fell through a trap-door, striking his head upon the wooden

floor about twenty feet below. Did not become immediately unconscious. Was put in a patrol-wagon, and was seen on his way home by a physician, who found no apparent serious condition present. About an hour after the injury he became unconscious. Shortly afterwards he was seen by Dr. Guy Gowen, who sent him to Wesley Hospital. When seen by Dr. Gowen he had spasms in the left upper extremity, which were soon followed by paralysis of that member.

When seen by the writer at the hospital five hours after the injury he presented all the cardinal symptoms of middle meningeal haemorrhage, compression-pulse, stertorous breathing, left hemiplegia, with history of a free interval and spasms preceding the hemiplegia. In the right temporal region was a slight doughy swelling. Pupils equal, medium dilatation. Temperature, 101.5° F.

Diagnosis before operation, haemorrhage from right middle meningeal artery, compression of brain, with probable fracture of skull in temporal region.

Operation five hours after injury. Hartley-Krause osteoplastic flap made on the right side. A haematoma was found in the temporal muscle. In cutting through the bone, the Devilbiss forceps, which acts upon the same principle as the Stille forceps, was used. The squamous portion of the temporal bone showed a linear fracture. Upon turning down the flap a haematoma medium was found. After removal of the clot, the proximal end of the ruptured anterior branch of the middle meningeal artery was seen to be bleeding freely and was ligated. It was now seen that the fracture extended to the base of the skull. Soon after the operation was begun, the rectal temperature of the patient was found to be 104° F., and this continued to rise rapidly, so that at the close of the operation it was 107° F. The removal of the clot caused no change in the condition of the patient, which steadily grew worse. The dura remained depressed, and a fractured portion of the bone of the flap, which had but poor connection with the soft parts, was removed. Wound closed.

Three hours after the close of the operation the patient died. The post-mortem temperature was 109.5° F.

Operative Diagnosis.—Rupture of the anterior branch of the right middle meningeal artery; haematoma medium; compression

of brain; fracture of skull in temporal region; fracture of base of skull.

Autopsy.—Six hours after death I had the privilege of examining the skull and its contents. There had been no further haemorrhage from the middle meningeal artery. The fracture extended across the squamous portion of the right temporal bone, across the great wing of the sphenoid on the right side, through the body of the sphenoid and into the great wing of the sphenoid on the left side. In the fourth ventricle was found a clot almost one-half centimetre in diameter.

Post-Mortem Diagnosis.—Same as operative diagnosis, with the addition of haemorrhage into the fourth ventricle.

Immediate cause of death, haemorrhage into the fourth ventricle.

CASE II.—*Subcutaneous Linear Fracture of Parietal Bone above Right Parietal Eminence; Rupture of Several Small Branches of Middle Meningeal Artery in this Location; Concussion of the Brain; Compression of the Brain; Haematoma Posticum; Partially Free Interval; Contralateral Hemiparesis; Osteoplastic Resection of Skull, with Enlargement of the Opening Upward and Backward; Removal of Clot; Iodoform Gauze Packing; Recovery.*

J. K.; aged thirty years; male; horse-shoer. Family history negative. Previous health good. On August 11, 1901, at about 5.30 P.M., while slightly under the influence of liquor, fell from a balcony, a distance of eight and a half feet, striking his head upon a concrete pavement. Became immediately unconscious, and was taken to Wesley Hospital twenty minutes after the reception of the injury. Was totally unconscious when he entered the hospital, but three-quarters of an hour after the injury he became partially conscious and could answer questions. The period of semiconsciousness was short, and he gradually lapsed into complete unconsciousness. At the same time paresis of left arm and leg developed, and the pulse gradually lowered. At 6.15 P.M. the pulse was 82 per minute; at 7.30 P.M., 64, and at 10.30 P.M., 52. It was the characteristic full, compression pulse. Pupils equal, medium dilatation. No fracture could be discovered; no wound or contusion of soft parts.

Diagnosis before operation, haemorrhage from right middle meningeal artery; compression of the brain.

Operation six hours after injury. No sign of injury to the scalp. Hartley-Krause osteoplastic flap made on the right side, as in Case I. No injury to the bone found in this neighborhood. Upon turning down the flap, the anterior branch of the artery, which was in a bony canal on the flap, was ruptured and ligated. At the upper posterior part of the exposed area was seen the edge of a haematoma. An incision through the soft parts was now made upward and backward two and a half inches, beginning at the upper posterior margin of the flap. This brought to view a linear fracture of the parietal bone two inches long, running parallel with the sagittal suture and lying one and a half inches below the suture. No depression. With the Devilbiss forceps a portion of bone one to one and a half inches wide was removed throughout the entire length of the incision through the soft parts, its upper posterior extremity being above and a little behind the parietal eminence, and reaching to within one and a half inches of the sagittal suture. This exposed the haematoma thoroughly, and the clot was removed with the fingers and the sharp spoon. A number of small branches of the middle meningeal artery were found bleeding beneath the side of the fracture. The dura was intact. Iodoform gauze packing. Weight of clot, two and a half ounces. The portion of bone removed from the parietal region was not replaced.

Operative Diagnosis.—Subcutaneous linear fracture, without depression, of right parietal bone above parietal eminence. Laceration of several small branches of the middle meningeal artery. Haematoma posticum. Compression of the brain.

Postoperative History.—Pulse at the close of operation, 122. Two and one-half hours after the operation he answered questions and moved his left leg; pulse, 132; axillary temperature, 100° F. Four and one-half hours after the operation he was fully conscious. The highest temperature was twenty-four hours after the operation, 100.8° F. in the axilla. On the fourth day the temperature became normal and remained so. The pulse became normal on the third day. Thirty hours after the operation the outside dressings were removed, being saturated with blood and serum. Fifty-six hours after the operation the gauze packing was removed, and fresh packing was inserted in greatly lessened amount. The wound was aseptic. Five days after the operation all packing was removed permanently, the dura now

being everywhere returned to its normal position. For four days the patient had to be catheterized. His progress after the fifth day was uneventful.

Present Condition.—He has been working steadily at his trade of horse-shoeing, but says he occasionally has pain in the scar when he stoops over at his work. The cold also makes the scar smart. The anaesthesia which at first was noticed in the scalp above the scar has disappeared. He has no headache, no vertigo, no periods of unconsciousness. The scar shows the height of the flap to be three inches, and its greatest breadth three and one-half inches.

These two cases confirm Krönlein's²⁸ observation that the result of operation for haematoma arising from middle meningeal haemorrhage is generally favorable unless compromised by simultaneous injuries resulting from the same cause as the haemorrhage. In Case I, if the extradural haematoma had been the only trouble, recovery could have been looked for, but the patient died from the concomitant haemorrhage into the fourth ventricle. The second case, being uncomplicated, recovered.

Wiesmann²⁹ reports several cases of extremely high temperature in haematoma from the middle meningeal artery. In several of the cases this was due to intercurrent causes, as erysipelas and bronchopneumonia. In others, the decomposition of the clot, where this had not been removed, accounts for it. The cases similar to Case I, in which the temperature rises to an extreme height in a few hours after the injury, he regards as not yet satisfactorily explained, not accepting as proven the theory of direct irritation of the heat-regulating centre.

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